612.40914X00

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: I. REY-FABRET ET AL.

Serial No.: New Application

Filed: December 21, 2001

For: METHOD FOR FORMING AN OPTIMIZED NEURAL NETWORK MODULE INTENDED TO SIMULATE THE FLOW MODE OF A MULTIPHASE FLUID STREAM

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

The following preliminary amendments and remarks are respectfully submitted in connection with the above-identified application.

IN THE SPECIFICATION:

Please replace the original specification with the attached Substitute Specification.

REMARKS

The specification has been amended to improve its form for examination. Applicants submit herewith a Substitute Specification, along with a marked-up copy of the original specification for the Examiner's convenience. The substitute specification includes the changes as shown in the marked-up copy and includes no

new matter. Therefore, entry of the Substitute Specification is respectfully requested.

The claims have been amended to improve their form for examination and to eliminate multiple dependencies.

The abstract has been amended to provide an abstract in proper format.

Entry of the preliminary amendment and examination of the application is respectfully requested.

To the extent necessary, applicant's petition for an extension of time under 37 CFR 1.136. Please charge any shortage in the fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account No. 01-2135 (612.40914X00) and please credit any excess fees to such deposit account.

Respectfully submitted,

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BACKGROUND OF THE INVENTION

Field Of The Invention

The present invention relates to a method for forming a neural network module for real-time simulation of the flow mode, at any point of a pipe, of a multiphase fluid stream comprising at least a liquid phase and at least a gas phase, that is best suited to operating conditions and to a set of fixed physical quantities.

Description of the Prior Art

Transporting hydrocarbons from production sites to treating plants constitutes an important link in the petroleum chain. It is a delicate link because of the complex interactions between the phases forming the transported effluents. The basic objective for operators is to reach an optimum productivity under the best safety conditions. They therefore have to control as best they can the velocity and the temperature so as to avoid unnecessary pressure drops, unwanted deposits and unsteady-state flows. The method that is generally used consists in modelling in the best possible way the transportation of complex multiphase streams so as to provide at all times an image of the flows in the various parts of the production chain, taking into account the precise constitution of the effluent, the flow rates, the pressures and the flow modes.

There are currently various software modules for simulating the transport of complex multiphase streams, allowing to design suitable production equipments at an early stage.

U.S. Patents 5,550,761, 6,028,992 and US-5,960,187 filed by the assignee notably describe modelling modules forming the TACITE model known in the art, allowing simulation of the transport of complex multiphase streams as a steady or transient flow and accounts for instability phenomena that occur because of the irregular geometry of the formation crossed by the pipe or of the topography thereof, referred to by specialists as "terrain slugging" or "severe slugging".

The simulation modules are as complex as the modelled phenomena. Precision and performances can only be obtained after a relatively long modelling time, which is not really compatible with real-time management. That is the reason why these modelling modules cannot be used as they are for real-time management of the production. It therefore appears necessary to use modelling methods offering a good compromise between calculating speed and accuracy of results.

French Patent application 00/09,889 filed by the assignee describes a method of real-time estimation of the flow mode, at any point of a pipe having a structure that can be defined by a certain number of structure parameters, of a multiphase fluid stream defined by several physical quantities and comprising liquid and gas phases. According to this method, the flow mode is modelled :

- by forming a non-linear neural network with an input layer having as many inputs as there are structure parameters and physical quantities necessary for good estimation of the output, an output layer with as many outputs as there are quantities necessary for estimation of the flow mode, and at least one intermediate layer,

- by forming a learning base with predetermined tables connecting various values obtained for the output data to the corresponding values of the input data, and

- by determining, by iterations, weighting factors of the activation function allowing proper connection of the values in the input and output data tables.

Output data of the neural network is preferably analyzed so as to sort, among the values of the output data of the neural network, only the pertinent data to be taken into account for iterative determination of the weighting coefficients of the activation function.

SUMMARY OF THE INVENTION

The method according to the invention forms a module (hydrodynamic or thermodynamic for example) which provides real-time simulation of the flow mode, at any point of a pipe, of a multiphase fluid stream comprising at least a liquid phase and at least a gas phase, so that it is best suited to fixed operating conditions concerning a certain number of determined structure and physical

parameters relative to the pipe, and a set of determined physical quantities (hydrodynamic or thermodynamic quantities for example), with fixed variation ranges for the parameters and the physical quantities.

The method of the invention comprises using a modelling system based on non-linear neural networks each having inputs for structure parameters and physical quantities, outputs where quantities necessary for estimation of the flow mode are available, and at least one intermediate layer. The neural networks are determined iteratively so as to adjust to the values of a learning base with predetermined tables connecting various values obtained for the output data to the corresponding values of the input data.

The method forms a learning base suited to the imposed operating conditions and optimized neural networks best adjusted to the imposed operating conditions are generated.

In the case, for example, where the module is to be integrated in a general multiphase flow simulation model, both hydrodynamic and thermodynamic, the model is used to form the learning base so as to select the set of physical quantities that is best suited to the model, as well as the variation ranges fixed for the parameters and the physical quantities, and the optimized neural networks that best adjust to the learning base formed are generated.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a neural network in accordance with the invention.

Fig. 2 is a table expressing classification percentage obtained for three output classes of the neural network of Fig. 1.

Fig. 3 is a table illustrating classification results.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

General points concerning the formation of the neural networks system

A circulation of multiphase fluids in a pipe with at least a liquid phase and at least a gas phase is considered in formation of a neural system providing, from a certain number of geometrical and physical input data relative to the pipe and of physical data relative to the fluids, instantaneously, for each section of the fluid stream, an estimation of the flow mode or, from a certain number of data linked with the pressure and temperature conditions of the fluid, and with the composition of the fluid, giving the thermodynamic behavior of the fluid. The whole of this input data constitutes a database.

1) Input and output data

The input data is for example :

- geometrical and physical data of the pipes : diameter, roughness and angle of inclination of the pipe, and thermodynamic data : density of the gas, density of the liquid, viscosity of the gas, viscosity of the liquid, etc. ; the whole of this data constitutes an n-uplet, and

- hydrodynamic data characterizing the mixture : gas/liquid surface tension, volume fraction of gas, barycentric velocity of the mixture, etc.,

or :

- thermodynamic data relative to the environment of the fluid : pressure, temperature, the whole of this data constituting an n-uplet, as well as data characterizing the composition of the mixture : molar mass, critical properties, enthalpy coefficients, etc.

The model produces for example at the output the hydrodynamic behavior of the effluents, and notably the flow regime. It evaluates and delivers at two main outputs hydrodynamic data in the part of the pipe where the flow type is to be determined, the velocity difference dV between gas and liquid for example, or the stratified type flow fraction β ($\beta \in [0\ ;1]$) (type where the liquid phase flows in the lower part of the pipe). Other quantities qualifying the flow type can be calculated from these two outputs.

In applications to thermodynamics, the model produces at the output the thermodynamic quantities of the effluents such as, for example, the number and the nature of the phases in presence or the molar fractions of the phases.

2) <u>Structure of the system of networks</u>

The function to be modelled by the hydrodynamic or thermodynamic model involves various subfunctions that can be solved by using, if necessary, several networks playing a well-determined part within the model. For example, a network can be dedicated to the non-linear function regression, while another network is dedicated to the classification of the various flow regimes. Besides, the connections to be established between the networks or between the module and its outer environment can require complementary data processing (data

normalization, denormalization, etc.). The system is therefore referred to as based on neural networks.

In order to connect the whole of the hydrodynamic or thermodynamic input and output data, a system of neural networks is formed, these networks being preferably of MLP type, well-known in the art since it is particularly well-suited for physical phenomena modelling. Its structure allows describing the dynamic as well as the static components of the phenomena, even by fixing, if necessary, some of its parameters at a rectified value, therefore physically representative. Thus, knowing physical equations that govern the flows allows, for example, enrichment of the network and a best adaption thereof to the physical phenomena modelled thereby.

The neural network comprises (Fig.1) three layers for example: the input layer of ten neurons corresponding to the ten data (mentioned above) of the complete physical model, an output layer of two neurons corresponding to the two parameters dV and β sought, and an intermediate layer, referred to as hidden layer, whose number of neurons N_c is optimized. The network is totally connected. The non-linearity of this network is obtained by a sigmoid activation function governing the behavior of the neurons in the hidden layer. The neurons of the output layer can be selected linear or non-linear. The activation function can be the identity function for example.

3) <u>Learning</u>

The weights of this structure are determined at the end of the learning stage; during this stage, the network is supplied with a set of data forming the

learning base of the network, and the structure and the weights of the network are optimized by minimizing the erros observed for all the samples of the base, between the output data resulting from network calculations and the data expected at the output, given by the base. The errors can be the absolute errors between the input and output quantities or the relative errors, according to the performance desired for the network.

The generalization powers of the network are then tested from its capacity to properly calculate the two outputs for inputs that are unknown thereto.

Implementation particularities

The system based on neural networks modelling the hydrodynamic module or the thermodynamic module is defined by a set of parameters that the learning base allows determination and fixing thereof. These parameters are adaptable to the constraints imposed by the use to which this module is dedicated.

If the module is intended for a general use, the learning base has to be exhaustive, i.e. include all the available data concerning the various inputs/outputs ; the module can thus represent all of the cases that can be encountered in the field.

If the module is used in a more specialized framework or context, production of an oil field for example, adjustment is carried out on a more restricted learning base containing only the data that can be encountered in this field alone : type or structure of the pipes or pipelines, topographic variations,

more restricted ranges of variation of certain hydrodynamic or thermodynamic quantities, etc. The parameters of the neural networks are in this case calculated so as to obtain a product specific to a given configuration, in order to represent in the best possible way the flows in operating ranges specific to this field.

This module is thus adaptable to the various described uses thereof.

Environment of the neural network module

The module developed can be used alone, without associated modules. In this case, the module is adjusted to databases formed according to the desired use, according to whether the context is general or specific. It is independent and allows estimation of the hydrodynamic or thermodynamic quantities likely for monitoring of the behavior of effluent flows in pipelines, from a learning base containing physical and thermodynamic quantities data provided otherwise.

The module can also be implemented in any model (set of simulation software modules capable of simulating the transient and/or steady behavior of multiphase flows, such as for example the TACITE model mentioned above). In this case, the module is adjusted to reference models representing the current state of the art, and to associated databases that widely cover the whole of the definition domain of the n-uplet formed by the input data. This adjustment thus takes into account the specificities of the software environment in which it is included.

To form the learning base that is best suited to the model where the neutral system is to be integrated, the model is advantageously used to connect the input and output data.

Examples of use

The module based on neural networks is suited for any application requiring hydrodynamic representation of effluents: formation of flow predictive simulation codes, real-time simulation or training simulation, etc. Active production control methods can also be based on such a module.

Optimization examples

Consider for example the case where a network giving the classification of the flow type of multiphase fluids to be optimizes: stratified type or class C1 flow (defined above), intermittent type or class C2 flow (characterized by a succession of liquid and gaseous slugs), or dispersed type or class C3 flow (the liquid being carried along in form of fine droplets), according to inputs as described above under the heading "General Points Concerning the Formation of the Network".

A neural network is first formed by means of a general base. The resulting optimum structure obtained contains 30 neurons, with a single hidden layer. The network confusion table obtained (Fig.2) expresses the classification percentage obtained in the three output classes of the network for each class of the database.

The database used is then restricted to particular configurations, which reduce the ranges of variation of the various inputs of the network. The optimum neural network consists in this case of 28 neurons and comprises a single hidden layer. The classification result is shown by the confusion table in Fig.3.

It can immediately be seen that the good classification results distributed over the diagonal are greatly improved in relation to the previous case, formed by means of a less selective base, less suited to the configuration to which the module is applied.

Adjustment of the database to the conditions of use thus allows, on the one hand, modification of the structure of the network and, on the other hand, to optimize the generalization results obtained.

We claim:

CLAIMS

1) A method for forming a module providing real-time simulation of a flow mode, at any point of a pipe, of a multiphase fluid stream comprising at least a liquid phase and at least a gas phase, for fixed operating conditions concerning a determined structure parameters relative to the pipe, and a set of determined physical quantities, with fixed variation ranges for the parameters and the physical quantities, by a modelling system based on non-linear neural networks each having inputs for the structure parameters and the physical quantities, outputs where quantities necessary for estimation of the flow mode are available, and at least one intermediate layer, comprising determining the neural network so as to adjust to values of a learning base with predetermined tables connecting values obtained for output data from the output to corresponding values of input data to the inputs and wherein the learning base imposes operating conditions and the determined neural networks are adjusted to the imposed operating conditions.

2) A method as claimed in claim 1, wherein the physical quantities are hydrodynamic quantities.

3) A method as claimed in claim 1, wherein the physical quantities are thermodynamic quantities.

4) A method as claimed in claim 2, wherein the module being integrated is a hydrodynamic and thermodynamic multiphase flow simulation model, the model being used to form the learning base to select the physical quantities best

suited to the model, variation ranges fixed for the parameters and the physical quantities, and an optimized neural networks best suited to the learning base.

PATENT

INSTITUT FRANÇAIS DU PETROLE

METHOD FOR FORMING AN OPTIMIZED NEURAL NETWORK MODULE INTENDED TO SIMULATE THE FLOW MODE OF A MULTIPHASE FLUID STREAM

Inventors : Isabelle REY-FABRET, Emmanuel DURET, Eric HEINTZE

and Véronique HENRIOT

ABSTRACT

A Method for forming a module (hydrodynamic or thermodynamic for example) ~~intended~~ for real-time simulation of the flow mode, at any point of a pipe, of a multiphase fluid stream comprising at least a liquid phase and at least a gas phase, so that it is best suited to fixed operating conditions concerning a certain number of determined structure and physical parameters relative to the pipe, and a set of determined physical quantities (hydrodynamic or thermodynamic quantities for example), with fixed variation ranges for the parameters and the physical quantities.

The method ~~It~~ comprises using a modelling system based on non-linear neural networks ~~having~~ each having inputs for structure parameters and physical quantities, outputs where quantities necessary for estimation of the flow mode are available, and at least one intermediate layer. The neural networks are determined iteratively to adjust to the values of a learning base with predetermined tables connecting various values obtained for the output data to the corresponding values of the input data. A learning base suited to the imposed operating conditions is used and optimized neural networks best adjusted to the imposed operating conditions are generated.

Applications : modelling of hydrocarbon flows in pipes for example.

FIELD OF THE INVENTION

The object of the present invention relate to is a method for forming a neural network module intended for real-time simulation of the flow mode, at any point of a pipe, of a multiphase fluid stream comprising at least a liquid phase and at least a gas phase, that is best suited to operating conditions and to a set of fixed physical quantities.

BACKGROUND OF THE INVENTION

Description of the Prior Art

Transporting hydrocarbons from production sites to treating plants constitutes an important link in the petroleum chain. It is a delicate link because of the complex interactions between the phases forming the transported effluents. The basic objective for operators is to reach an optimum productivity under the best safety conditions. They therefore have to control as best they can the velocity and the temperature so as to avoid unnecessary pressure drops, unwanted deposits and unsteady-state flows. The method that is generally used consists in modelling in the best possible way the transportation of complex multiphase streams so as to provide at all times an image of the flows in the various parts of the production chain, taking into account the precise constitution of the effluent, the flow rates, the pressures and the flow modes.

There are currently various software modules for simulating the transport of complex multiphase streams, allowing to design suitable production equipments at an early stage.

US Patents (US-5,550,761, FR-2,756,044 (US-6,028,992) and FR-2,756,045 (US-5,960,187) filed by the assignee ~~applicant~~ notably describe modelling modules forming the TACITE model known to the man skilled in the art, allowing ~~to~~ simulation of the transport

of complex multiphase streams ~~on~~ and a steady or transient flow and capable of taking into account instability phenomena that occur because of the irregular geometry of the formation crossed by the pipe or of the topography thereof, referred to by specialists as « terrain slugging » or « severe slugging ».

The simulation modules are as complex as the modelled phenomena. Precision and performances can only be obtained after a relatively long modelling time, which is not really compatible with real-time management. That is the reason why these modelling modules cannot be used as they are for real-time management of the production. It therefore appears necessary to use modelling methods offering a good compromise between calculating speed and accuracy of results.

French Patent application FR-00/09,889 filed by the ~~applicant~~ company describes a method intended for real-time estimation of the flow mode, at any point of a pipe having a structure that can be defined by a certain number of structure parameters, of a multiphase fluid stream defined by several physical quantities and comprising liquid and gas phases. According to this method, the flow mode is modelled :

- by forming a non-linear neural network with an input layer having as many inputs as there are structure parameters and physical quantities necessary for good estimation of the output, an output layer with as many outputs as there are quantities necessary for estimation of the flow mode, and at least one intermediate layer,

- by forming a learning base with predetermined tables connecting various values obtained for the output data to the corresponding values of the input data, and

- by determining, by iterations, weighting factors of the activation function allowing to properly connect the values in the input and output data tables.

Output data of the neural network is preferably analysed so as to sort, among the values of the output data of the neural network, only the pertinent data to be taken into account for iterative determination of the weighting coefficients of the activation function.

SUMMARY OF THE INVENTION

The method according to the invention allows to form a module (hydrodynamic or thermodynamic for example) intended for real-time simulation of the flow mode, at any point of a pipe, of a multiphase fluid stream comprising at least a liquid phase and at least a gas phase, so that it is best suited to fixed operating conditions concerning a ~~certain~~ number of determined structure and physical parameters relative to the pipe, and a set of determined physical quantities (hydrodynamic or thermodynamic quantities for example), with fixed variation ranges for the parameters and the physical quantities.

The method of the invention

~~It~~ comprises using a modelling system based on non-linear neural networks ~~having~~ each having inputs for structure parameters and physical quantities, outputs where quantities necessary for estimation of the flow mode are available, and at least one intermediate layer. The neural networks are determined iteratively so as to adjust to the values of a learning base with predetermined tables connecting various values obtained for the output data to the corresponding values of the input data.

The method is characterized in that a learning base suited to the imposed operating conditions is formed and optimized neural networks best adjusted to the imposed operating conditions are generated.

In the case, for example, where the module is to be integrated in a general multiphase flow simulation model, both hydrodynamic and thermodynamic, the model is used to form the learning base so as to select the set of physical quantities that is best suited to the model, as well as the variation ranges fixed for ~~said~~ the parameters and ~~said~~ the physical quantities, and the optimized neural networks that best adjust to the learning base formed are generated.

BRIEF DESCRIPTION OF THE DRAWINGS

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DETAILED DESCRIPTION of the PREFERRED EMBODIMENTS OF THE INVENTION

General points concerning the formation of the neural networks system

~~We consider~~ A ~~a~~ circulation of multiphase fluids in a pipe with at least a liquid phase and at least a gas phase is considered in formation of and we try to ~~form~~ a neural system allowing monitoring, from a certain number of geometrical and physical input data relative to the pipe and of physical data relative to the fluids, to give instantly instantaneously, for each section of the fluid stream, an estimation of the flow mode or, from a ~~certain~~ number of data linked with the pressure and temperature conditions of the fluid, and with the composition of the fluid, ~~to~~ giving the thermodynamic behavior of the fluid. The whole of this input data constitutes a database.

1) Input and output data

The input data is for example :

- geometrical and physical data of the pipes : diameter, roughness and angle of inclination of the pipe, and thermodynamic data : density of the gas, density of the liquid, viscosity of the gas, viscosity of the liquid, etc. ; the whole of this data constitutes an n-uplet, and

* Fig. 1 illustrates a neural network in accordance with the invention
Fig. 2 is a table expressing classification percentages obtained for three output classes of the neural network of Fig. 1
Fig. 3 is a table illustrating classification results

- hydrodynamic data characterizing the mixture : gas/liquid surface tension, volume fraction of gas, barycentric velocity of the mixture, etc.,

or :

- thermodynamic data relative to the environment of the fluid : pressure, temperature, the whole of this data constituting an n-uplet, as well as data characterizing the composition of the mixture : molar mass, critical properties, enthalpy coefficients, etc.

The model produces for example at the output the hydrodynamic behaviour of the effluents, and notably the flow regime. It evaluates and delivers at two main outputs hydrodynamic data in the part of the pipe where the flow type is to be determined, the velocity difference dV between gas and liquid for example, or the stratified type flow fraction β (β ∈ [0 ;1]) (type where the liquid phase flows in the lower part of the pipe). Other quantities qualifying the flow type can be calculated from these two outputs.

In applications to thermodynamics, the model produces at the output the thermodynamic quantities of the effluents such as, for example, the number and the nature of the phases in presence or the molar fractions of the phases.

2) Structure of the system of networks

The function to be modelled by the hydrodynamic or thermodynamic model involves various subfunctions that can be solved by using, if necessary, several networks playing a well-determined part within the model. For example, a network can be dedicated to the non-linear function regression, while another network is dedicated to the classification of the various flow regimes. Besides, the connections to be established between the networks or between the module and its outer environment can require

complementary data processing (data normalization, denormalization, etc.). The system is therefore referred to as based on neural networks.

In order to connect the whole of the hydrodynamic or thermodynamic input and output data, a system of neural networks is formed, these networks being preferably of MLP type, well-known to the man skilled in the art, since it is particularly well-suited for physical phenomena modelling. Its structure allows to describ~~e~~ ing the dynamic as well as the static components of the phenomena, even by fixing, if necessary, some of its parameters at a ~~reified~~ rectified value, therefore physically representative. Thus, knowing physical equations that govern the flows allows for example ~~to~~ enrich ment of the network and ~~to~~ a best ~~adapt it~~ adaptation thereof to the physical phenomena modelled thereby.

The neural network comprises (Fig.1) three layers for example : the input layer consisting of ten neurons corresponding to the ten data (mentioned above) of the complete physical model, an output layer consisting of two neurons corresponding to the two parameters dV and β sought, and an intermediate layer, referred to as hidden layer, whose number of neurons N_c is optimized. The network is totally connected. The non-linearity of this network is obtained by a sigmoid activation function governing the behavio~~u~~r of the neurons in the hidden layer. The neurons of the output layer can be selected linear or non-linear. The activation function can be the identity function for example.

3) Learning

The weights of this structure are determined at the end of a learning stage ; during this stage, the network is supplied with a set of data forming the learning base of the network, and the structure and the weights of the network are optimized by minimizing

the errors observed for all the samples of the base, between the output data resulting from network calculations and the data expected at the output, given by the base. The errors can be the absolute errors between the input and output quantities or the relative errors, according to the performance desired for the network.

The generalization powers of the network are then tested from its capacity to properly calculate the two outputs for inputs that are unknown thereto.

Implementation particularities

The system based on neural networks modelling the hydrodynamic module or the thermodynamic module is defined by a set of parameters that the learning base allows ~~to~~ determin~~e~~ation and ~~to~~ fix ing those. These parameters are adaptable to the constraints imposed by the use to which this module is dedicated.

If the module is intended for ~~use in a~~ general use ~~context~~, the learning base used has to be exhaustive, i.e. include all the available data concerning the various inputs/outputs ; the module can thus represent all of the cases that can be encountered in the field.

If the module is intended for used in a more specialized framework or context, production of an oil field for example, adjustment is carried out on a more restricted learning base containing only the data that can be encountered in this field alone : type or structure of the pipes or pipelines, topographic variations, more restricted ranges of variation of certain hydrodynamic or thermodynamic quantities, etc. The parameters of the neural networks are in this case calculated so as to obtain a product specific to a given configuration, in order to represent in the best possible way the flows in operating ranges specific to this field.

This module is thus adaptable to the various described objectives fixing the use thereof.

Environment of the neural network module

The module developed can be used alone, without associated modules. In this case, the module ~~it~~ is adjusted to databases formed according to the desired use, according to whether the context is general or specific. It is independent and allows ~~to~~ estimation of ~~estimate~~ the hydrodynamic or thermodynamic quantities likely ~~to allow~~ for monitoring of the behavior of effluent flows in pipelines, from a learning base containing physical and thermodynamic quantities data provided otherwise.

The module can also be implemented in any model (set of simulation software modules capable of simulating the transient and/or steady behavior of multiphase flows, such as for example the TACITE model mentioned above). In this case, the module is adjusted to reference models representing the current state of the art, and to associated databases that widely cover the whole of the definition domain of the n-uplet formed by the input data. This adjustment thus takes into account the specificities of the software environment in which it is included.

To form the learning base that is best suited to the model where the neural system is to be integrated, the model is advantageously used to connect the input and output data.

Examples of use

The module based on neural networks is suited for any application requiring hydrodynamic representation of effluents : formation of flow predictive simulation codes, real-time simulation or training simulation, etc. Active production control methods can also be based on such a module.

Optimization examples

Consider for example the case where a network giving the classification of the flow type of multiphase fluids is to be optimized : stratified type or class C1 flow (defined above), intermittent type or class C2 flow (characterized by a succession of liquid and gaseous slugs), or dispersed type or class C3 flow (the liquid being carried along in form of fine droplets), according to inputs as described above under the heading in paragraph « General points concerning the formation of the network ».

A neural network is first formed by means of a general base. The resulting optimum structure obtained contains 30 neurons, with a single hidden layer. The network confusion table obtained (Fig.2) expresses the classification percentage obtained in the three output classes of the network for each class of the database.

The database used is then restricted to some particular configurations, which reduce the ranges of variation of the various inputs of the network. The optimum neural network consists in this case of 28 neurons and comprises a single hidden layer. The classification result is shown by the confusion table in Fig.3.

It can immediately be seen that the good classification results distributed over the diagonal are greatly improved in relation to the previous case, formed by means of a less selective base, less suited to the configuration to which the module is applied.

Adjustment of the database to the conditions of use thus allows, on the one hand, ~~to~~ modify ification of the structure of the network and, on the other hand, to optimize the generalization results obtained.

We claim:

CLAIMS

1) A method for forming a module intended for provides real-time simulation of ~~the~~ a flow mode, at any point of a pipe, of a multiphase fluid stream comprising at least a liquid phase and at least a gas phase, so that it is best suited to for ~~fixed~~ operating conditions concerning ~~a certain number of~~ determined structure parameters relative to the pipe, and a set of determined physical quantities, with fixed variation ranges for ~~said~~ the parameters and ~~said~~ the physical quantities, by means of a modelling system based on non-linear neural networks having each inputs for the structure parameters and the physical quantities, outputs where quantities necessary for estimation of the flow mode are available, and at least one intermediate layer, comprising the neural networks being determined determining the neural networks iteratively so ~~as~~ to adjust ~~to the~~ to values ~~of~~ a learning base with predetermined tables connecting ~~various~~ values obtained for ~~the~~ output data from the output to ~~the~~ corresponding values of ~~the~~ inputs data to the inputs, ~~characterized in that~~ and wherein the learning base ~~suited to the~~ imposed operating conditions is formed and ~~optimized~~ the neural networks best adjusting generated to the imposed operating conditions are generated.

2) A method as claimed in claim 1, characterized in that wherein the set of physical quantities consists of are hydrodynamic quantities.

3) A method as claimed in claim 1, characterized in that wherein the set of the physical quantities consists of are thermodynamic quantities.

4) A method as claimed in any one of the previous claims 1, characterized in that, wherein said the module being integrated in a general, both hydrodynamic and thermodynamic multiphase flow simulation model, ~~said~~ the model ~~is~~ being used to form the learning base so as to

select the ~~set of~~ physical quantities ~~that is~~ best suited to the model, as well as the variation ranges fixed for ~~said~~ th parameters and ~~said~~ th physical quantities, and the optimized neural networks best suited to the learning base formed are generated.

PATENT

INSTITUT FRANÇAIS DU PETROLE

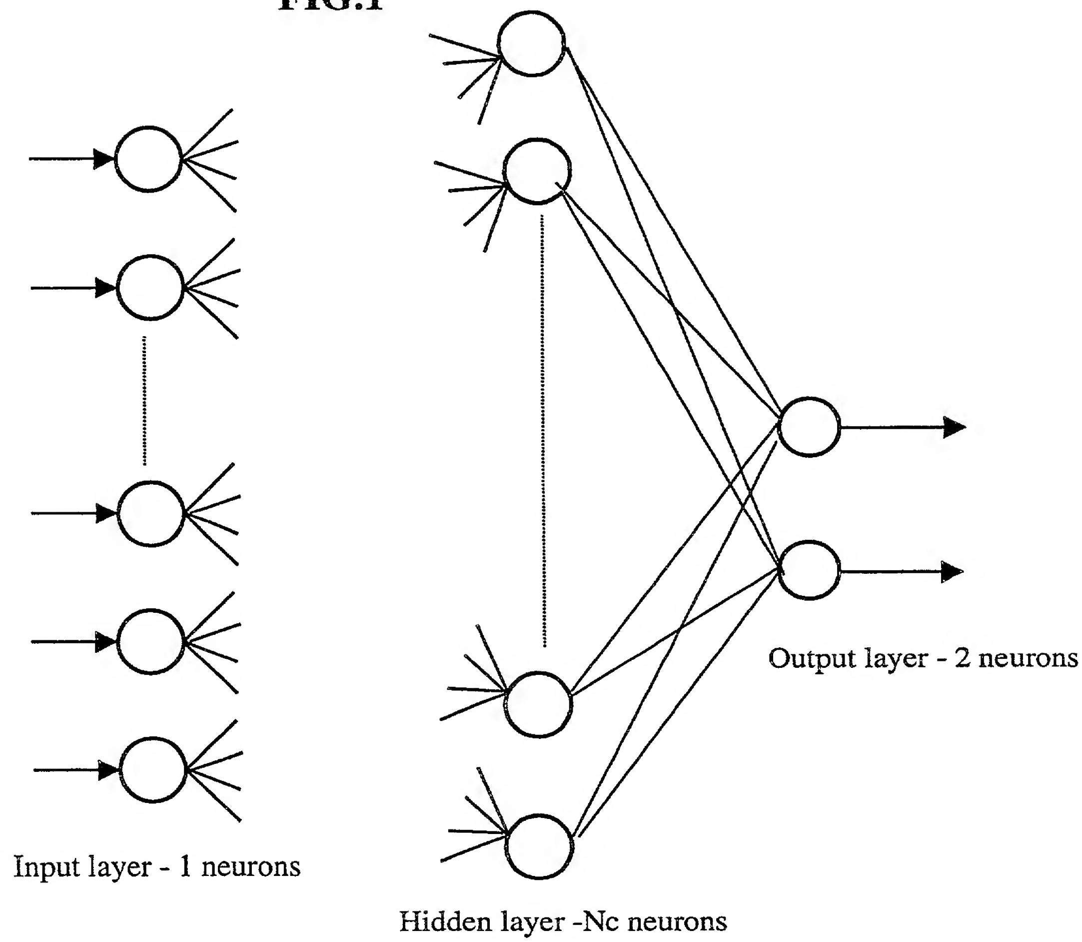
METHOD FOR FORMING AN OPTIMIZED NEURAL NETWORK MODULE INTENDED TO SIMULATE THE FLOW MODE OF A MULTIPHASE FLUID STREAM

Inventors : Isabelle REY-FABRET, Emmanuel DURET, Eric HEINTZE and Véronique HENRIOT

ABSTRACT

A method for forming a module (hydrodynamic or thermodynamic for example) intended for real-time simulation of the flow mode, at any point of a pipe, of a multiphase fluid stream comprising at least a liquid phase and at least a gas phase. The method comprises using a modelling system based on non-linear neural networks each having inputs for structure parameters and physical quantities, outputs where quantities necessary for estimation of the flow mode are available, and at least one intermediate layer. The neural networks are determined iteratively to adjust to the values of a learning base with predetermined tables connecting various values obtained for the output data to the corresponding values of the input data. A learning base suited to the imposed operating conditions is used and optimized neural networks best adjusted to the imposed operating conditions are generated.

FIG.1



	ESTIMATION			
DATA	C1={β=0}	C2={0<β<1}	C3={β=1}	
C1={β=0}	**87.3%**	10.7%	2%	100 %
C2={0<β<1}	3.1%	**81.5%**	15.4%	100 %
C3={β=1}	0.2%	4.8%	**95%**	100 %

Fig.2

	ESTIMATION			
DATA	C1={β=0}	C2={0<β<1}	C3={β=1}	
C1={β=0}	**99.49%**	0.5%	0.01%	100 %
C2={0<β<1}	1%	**98.3%**	0.7%	100 %
C3={β=1}	0.05%	2.9%	**97%**	100 %

Fig.3